ROYAL GARDENS, KEW.

BULLETIN

OF

MISCELLANEOUS INFORMATION.

No. 10.] OCTOBER. [1887.

XIX.—ONION DISEASE AT BERMUDA.

(*Peronospora Schleideniana*, De Bary.)

The current *Bulletin* is occupied with the results of an inquiry conducted under the auspices of the Royal Gardens, into a disease prevalent at the Bermudas affecting the onion crop, which is a staple industry of these small islands. Owing to climate and geographical position these islands are enabled to raise large quantities of early vegetables, which are shipped and sold at New York at a time when the corresponding American produce has as yet scarcely shown itself above ground. The onion crop, amongst others, raised from seed obtained from Teneriffe, has hitherto proved most productive; but owing to causes which are discussed in the following pages, this crop has latterly proved less remunerative. An inquiry was desired in the interest of cultivators, and this inquiry was undertaken by Mr. Arthur Shipley, B.A., Fellow of Christ's College, Cambridge. Mr. Shipley's reports deal with the circumstances connected with raising and harvesting of onion seed at Teneriffe, and with an exhaustive inquiry carried on at Bermuda, while the usual crop of onions was being raised for the American market. The results of the inquiry are given with great clearness by Mr. Shipley, and remedial and other measures are suggested which deserve the attention which no doubt they will receive from the persons directly interested.

LONDON:
PRINTED FOR HER MAJESTY'S STATIONERY OFFICE,
BY EYRE AND SPOTTISWOODE,
PRINTERS TO THE QUEEN'S MOST EXCELLENT MAJESTY.

And to be purchased, either directly or through any Bookseller, from
EYRE AND SPOTTISWOODE, EAST HARDING STREET, FLEET STREET, E.C.; or
ADAM AND CHARLES BLACK, 6, NORTH BRIDGE, EDINBURGH; or
HODGES, FIGGIS, & Co., 104, GRAFTON STREET, DUBLIN.

1887.

Price Twopence.

From Governor and Commander-in-Chief of Bermuda to the Director, Royal Gardens, Kew.

Government House,
Mount Langton, Bermuda,
July 1, 1886.

Sir,

The Legislature of this Colony have voted a sum of money for the purpose of securing the services for a short time of an agricultural chemist, or other qualified person, to inquire and examine into the causes of the onion disease which exists in these islands, and to suggest a remedy.

It is believed that the cause is a small fly, which attacks the leaf and prevents in many cases the formation of the bulb.

It is impossible, so far, to say whether this particular fly is imported in the seed from Teneriffe (whence nearly all the seed is imported), or whether it is bred on the spot. The idea which finds favour with the Board of Agriculture here, is to send a qualified person to Teneriffe to examine and report on the method of raising seed, and whether there is, or has been, any failure of crop from disease or otherwise, and subsequently, for the same person to visit Bermuda during the growth of the onion crop (which is the staple crop of the island), and continue his researches on the spot.

I shall feel greatly obliged if you can recommend a gentleman to this service, and will state what annual salary he will require, which of course will be in addition to his actual travelling expenses.

Believe me, &c.,
T. L. J. Gallwey,
Governor and Commander-in-Chief.

From Royal Gardens, Kew, to Colonial Office.

Sir,

August 12, 1886.

I have the honour to enclose a copy of a letter which I have received from the Governor of Bermuda, respecting the mission of a qualified person to that Colony, and to Teneriffe, for the purpose of inquiring into the failure of the onion crop in the former island.

As the culture of this vegetable is one of the principal industries of the Colony, I regard the steps taken by the Legislature as judicious.

After some inquiry I have ascertained that Mr. Arthur E. Shipley, Demonstrator of Comparative Anatomy in the University of Cambridge, is willing to undertake the mission, and is well qualified for it.

His official duties at Cambridge require his presence there after October. The present appears to be the proper time to investigate the circumstances of the harvesting of the onion seed in Teneriffe. Mr. Shipley is willing to go at once to that island; and I am of opinion that that is the best course that can be taken.

I am, &c.,
W. T. Thiselton Dyer.

E. Wingfield, Esq.,
Colonial Office.

From Colonial Office to Royal Gardens, Kew.

Downing Street,
14th August 1886.

Sir,

In reply to your letter of the 12th instant I am directed by Mr. Secretary Stanhope to request you to inform Mr. Arthur Shipley

that he will be obliged to him if he will at once proceed to Teneriffe to investigate the circumstances of the harvesting of the onion seed there, with a view to his subsequently visiting Bermuda to inquire into and report upon the failure of the onion crop in that Colony.

A copy of your letter will be transmitted to the Governor of Bermuda.

I am, &c.,

EDWARD WINGFIELD.

REPORT by MR. ARTHUR SHIPLEY on the ONION CROP in the CANARY ISLANDS.

Having been requested by Mr. Secretary Stanhope to proceed to Teneriffe to investigate the circumstances of the harvesting of the onion seed there, I left England on the 20th August 1886, and proceeded to Teneriffe viâ Madeira. I landed at Santa Cruz on the 28th of August. I spent a week in this town making inquiries and interviewing the principal onion growers in the south end of the island; I then crossed over to Grand Canary, and having spent a few days there returned to Teneriffe and spent a fortnight at Orotava on the north side of the island; amongst other places I visited Tejina and spent some time with the onion farmer who supplies a great part of the seed of the red variety of onion for export. I left Santa Cruz for England on the 27th of September, and landed at Plymouth on the 2nd of October.

I am much indebted for information and assistance to the following gentlemen:—Her Majesty's Consul Mr. Dupuis, Mr. Charles and Mr. Hugh Hamilton; Dr. Victor Perez and Mr. George Perez; Mr. Reid, Her Majesty's Vice-Consul at Orotava; and to Herr Wildpret, Curator of the Botanical Gardens at Orotava; and Mr. Mackay, United States Consul at Santa Cruz.

Varieties of onions.

There are two varieties of onion grown in the Canary Islands, the white and the red. These varieties are not permanent, but pass into one another under altered conditions of the soil, &c. The white variety is chiefly grown in the Island of Palma and on the south side of Teneriffe, in the neighbourhood of Santa Cruz. Those grown in Teneriffe gradually lose their character, become reddish in colour, and after three years cultivation are indistinguishable from the red variety. Those, however, grown in the island of Palma maintain their character unchanged, hence the seed for export is obtained from the latter island. The red variety is grown on the north side of Teneriffe, chiefly in the neighbourhood of Tejina.

Method of cultivation.

The onions are grown from seed which is scattered by hand during the month of October. The seedlings are transplanted into new beds in the month of December. Before placing in the earth the end of the leaves is cut off for about one or two inches. The young plants are planted in rows at intervals of about eight inches. The harvesting of the onions commences about the 10th of April and continues through the latter part of April and May. The white variety comes into the market a little earlier than the red, and hence commands a better price. When gathered, the onions are left lying on the land for three or four days to dry in the sun; they are then strung into ropes, and so prepared for sale. Only one crop a year is obtained.

Soil.

The soil is very light, and the ploughing very shallow. The fields are prepared by clearing a piece of waste of rocks, stones, &c., and then spreading a thin layer of earth on the floor of volcanic rock,

pumice stone, &c.; these are very porous, hence the plantations are particularly well drained.

Manure. As a rule only farm-yard manure is used, but in rare cases Peruvian guano; and a special kind of manure first prepared for the Cochineal plantations and known as Cactus guano, is employed with very good results in some parts of the island.

Irrigation. The young plants require frequent irrigation, the seedling before transplanting being well soaked eight or ten times.

Rotation of crops. The strain of onions is preserved from deterioration by alternating the onion crop with Indian corn, or more usually with potatoes, or by planting the onions in newly cleared ground. Thus the same field does not bear onions in two successive years.

Seed crop. Some of the bulbs from each crop of onions are set aside for the production of seed. These bulbs are replanted sometime during November in furrows about one foot wide, and at a distance of about 12 inches or 14 inches apart from one another. This distance is greater than exists between the onions grown for the bulb, which are planted too near one another to produce good "heads." Before planting the bulbs for seed, the top of each bulb is sliced off: by this means the number of heads arising from each bulb is increased; sometimes as many as 10 heads will grow from one bulb. The young heads begin to appear above ground about 14 days after planting. The heads ripen during the end of June and the first half of July, and as each head matures it is picked; the onion grower goes over the field every day and picks out the ripe ones. The heads are then spread on sheets and dried in the sun, and the seed is separated by rubbing with the hand.

About 1 lb. of seed is produced from every 20 onions, but the red seed is slightly heavier than the white. [All the growers were of opinion that the seed for planting in the autumn must be gathered in the summer of the same year, and that last year's seed will not germinate.]*

Method of packing the seed, &c. The seed for export to the Bermudas is packed in air-tight tins which are soldered down. These are shipped towards the end of July, viâ Liverpool and New York. Great pains are taken to ensure that the seed is new, though as no difference can be detected between new and old seed, the merchants are largely dependent on the honesty of the cultivators not to mix the seed.

Amount of seed shipped, prices, &c. There has been no falling off in the amount of onion seed exported from the islands in the last few years. The amount shipped during the last three years is roughly as follows:—

1884 - -	1,600 lbs. white seed.	3,300 lbs. red seed.
1885 - -	2,250 ,, ,,	4,200 ,, ,,
1886 - -	2,450 ,, ,,	4,000 ,, ,,

It will be noticed that the amount of red seed shipped is almost double the amount of white.

The prices are about 3*s.* per lb. for the white, and 1*s.* 6*d.* per lb. for the red seed.

By far the largest amount of seed exported is sent to the Bermudas, though a small but steadily increasing amount is supplied to the United States; and it is worthy of remark that the merchant who ships this, Mr. Mackay, United States Consul at Santa Cruz, has received no

* In Vilmorin Andrieux's standard work, "The Vegetable Garden," it is stated that onion seed does not lose its germinating power for two years.

complaint as to any failure of crops from his correspondents in America, although the crops in Bermuda raised from the same seed are reported to be very defective.

Prices of onions.

The shipping prices for the onions themselves this year (1886) were from 3*s.* to 4*s.* 6*d.* a quintal (100 lbs.) for the white, and 2*s.* 6*d.* to 4*s.* a quintal for the red. The white variety comes into the market rather earlier than the red and thus commands a rather higher price.

Diseases or other causes of failure in the onion crop.

The onions grown in the Canary Islands suffer from two distinct diseases, in addition to which sometimes the plants wither after being transplanted; this seems to be caused either by unfavourable atmospheric conditions at the time of planting or by the plant failing to strike root.

Hitherto none of these have caused any failure in the crop or given rise to much anxiety amongst the cultivators. The loss has never exceeded 20 per cent., and that is very exceptional.

I. La Escarcha or La Ceniza.

The disease which is called in the islands La Escarcha (hoar frost) or La Ceniza (ashes), takes the form of a light powder which is found on the leaves of the affected plant. At its first appearance the powder is of a light ashy colour, but as the disease increases it becomes darker, and if the plant is severely attacked, quite black, giving a velvety appearance to the leaf. The powder occurs all over the leaf and on all the leaves of an attacked plant. Some cultivators say that it does not occur uniformly throughout the plantation, but only in patches here and there, others say that the whole crop is affected, but in some places much more intensely than in others.

The disease attacks plants on all kinds of land, and hence it is difficult to avoid, but it is not feared so much as the second disease—the Quesillo—because it does not rot or destroy the bulb, but only arrests its growth. The onions remain small, but can still be used. Since the growth of the plant is arrested no head is produced, and the plant gives no seed. The disease attacks both red and white varieties of onions indifferently, but the former resist it slightly better.

The most favourable atmospheric conditions for the development of this disease is when a heavy dew falls after a long period of drought. The powder then makes its appearance on the leaves. A heavy shower, or artificial watering, or, in some cases, a high wind will sometimes cleanse them; hence well-sheltered plantations are favourable to the progress of the disease.

It is highly probable that this disease is caused by a fungus; it is often spoken of in the islands as the Onion Oidium, in some parts it is usual to dust the leaves with flowers of sulphur, and generally the same means are taken to arrest its progress as prove efficacious with the *Oidium Tuckeri* of the vine.

It is worth notice that plantations near the sea never suffer, except perhaps a few plants growing close under a wall.

II. El quesillo.

This disease is more feared than the foregoing, because it not only arrests the growth of the plant, but it rots and destroys the bulb itself. It usually makes its appearance when the bulbs have already attained a large size; and it commences by a blackening and subsequent rotting of the roots.

The parts of the plant above ground show but very slight signs of being affected; at most the leaves begin to lose colour, their tips especially becoming paler; so that as a rule it is not until the plants are gathered that the disease is first noticed. Then it is seen that the roots and usually the outer leaves of the bulb are black and rotten.

The bulb inside is sound, but if the outer layer of leaves is removed the next layer becomes affected.

It is impossible to make any use of the onions attacked by Quesilio, as they cannot be strung into ropes, since the leaves become rotten after the plant is gathered.

This disease occurs chiefly in damp places, especially in heavy clayey soils, but if the ground is carefully chosen, well worked and drained, there is no cause to fear it. In a plantation it usually occurs in patches, such patches corresponding with the dampest parts of the field.

Nothing is definitely known as to the nature of this disease, but all the symptoms point to the conclusion that it is caused by a fungus.

Another form of evil which injures the onion crop, affects the young plants a day or two after they have been transplanted in December. The leaves begin to fade and fall back in themselves, becoming at the same time whitish in colour, and the plant ceases to grow. Since this takes place quite at the beginning of the cultivation, it is easily repaired by pulling up the faded plants and replacing them by healthy ones.

This fading is probably to be attributed either to unfavourable weather at the time of transplanting or to the young plants failing to strike root.

Absence of insect injuries.

There appears to be no trace in the Canary Islands of any insect injury to the onion crop, such as is common in the English onion fields. I interviewed many of the large onion growers in different parts of the Island, and they were all unanimous in declaring that no such insect as the onion-fly or indeed any kind of insect ever attacked their crops. Further, I examined numerous samples of onions and failed to find any trace either of the insect or its grub. Neither could anything abnormal be detected in the seeds.

The onions have in no way deteriorated in quality during the last few years; the prices are certainly lower, but this is due to the fact that increased production in other parts of the world has lessened the demand, and not to any falling off in the quality of the plants.

The facts that the main crops in the Island still continue good, and that those grown in the United States from seed exported from Teneriffe are successful, seem to prove that the seed itself is good. It cannot be gathered from plants attacked with the Escarcha or Quesillo, as their growth is arrested, and they do not produce heads. It might, however, be advisable to recommend renewed precautions to ensure that none of last year's seed should be mixed with this year's, if, as the growers assert, the seed loses its germinating power after one year. It might also be worth while to try some other means of packing the seed, which would keep it dry, and at the same time admit the access of air. The present method of hermetically sealing it up for four or five weeks, especially if it is not thoroughly dry, may perhaps prove a source of danger.

ARTHUR E. SHIPLEY.

Christ's College, Cambridge.
October 9, 1886.

REPORT by MR. ARTHUR SHIPLEY on the ONION DISEASE in the BERMUDAS.

Preliminary.

At the request of Mr. Secretary Stanhope, I visited the Bermuda Islands in the beginning of the year 1887, to inquire into the causes of a disease prevalent among the onion crops during the preceding seasons, and if possible to suggest remedial measures.

I left England about the middle of January, and reached Bermuda the last day of the same month, and I remained in the Colony until the latter end of April.

The season of the year during which I was in Bermuda permitted me to see the whole growth and method of culture of the onion, from the time when it first appears above ground until it is pulled and packed for exportation.

Whilst in Bermuda I lived at Hamilton, and established there a small laboratory for the experimental investigation of the diseased plants. From Hamilton I visited all parts of the Island, and inspected many plantations. Some of them were suffering from a specific disease, others, however, were simply suffering from drought, which had caused the ends of the leaves to shrivel and fall back; again other crops were looking weak and unhealthy from the poverty of the soil upon which they were cultivated.

During my sojourn in the Bermudas, I received every possible attention and help from the officials of the Colony, and also from the farmers, who afforded me every facility for carrying out my investigations, and I take this opportunity of tendering my thanks for the assistance I received from everyone whilst carrying on my investigations.

On my way back to England I took the opportunity, whilst in the United States, of visiting Professor Farlow, of Harvard University, Cambridge, Mass., the eminent authority upon plant diseases, and consulting with him upon the best remedies to adopt for the disease. Professor Farlow had previously been in correspondence about the onion disease with some of the members of the Agricultural Board.

It was not until I returned to England that I could procure the books necessary for the completion of my report, and here I had the advantage of the assistance of Professor Marshall Ward of the Indian Civil Engineering College, a well-known authority upon fungoid diseases.

Sect. I.—The Disease and its Cause.

Disease during 1887.

The amount of disease amongst the onion plantations during the season of 1887 was decidedly less than during the preceding year. This was probably due to the atmospheric conditions being unfavourable to the propagation and development of the fungus causing the disease.

The cause of the disease.

The disease amongst the onions in Bermuda is caused by the presence of a microscopic fungus which lives parasitically upon the leaves of the Onion plant. This fungus is known to botanists under the name of *Peronospora Schleideniana*, De Bary, (*Botrytis Destructor*, Berkeley,) and amongst the onion farmers of the Old World as the Onion Mildew.

It belongs to the same order of fungi as the well-known potato fungus. Its geographical distribution is not well known, but it occurs in England, Germany, and has, I believe, been found in the United States.

Symptoms of the disease.

The first sign of the disease in an onion-patch is the appearance of a silvery white powder which lies scattered on the upper (inner) surface of the leaves of the onion plant, usually about three or four inches from the base of the leaf. This powdery growth gradually spreads over the whole leaf, which at the same time loses its plump consistency and becomes hard and resistent when felt. After some days the powder which at first has a silvery-white appearance assumes a greyish-black hue.

The leaves of the affected plant maintain their ordinary erect position for some time, their tops then turn inwards, and then ultimately dry up, wither, and fall back. (Fig. 1.)

All growth of the bulb is arrested as soon as the fungus has taken a good hold on the onion plant. This is due to the fact that the nutrition and other functions of the plant are interfered with by the presence of the fungus living parasitically upon the onion leaves. The fungus does not itself attack the bulb, and the bulb does not rot, so that if the plants are attacked when fully grown or almost so, the crop is not destroyed.

On its first appearance the fungus has a stimulating effect upon the growth of the onion plant. This is shown by the shooting up of a long neck between the top of the bulb and the base of the leaves; or, in other words, instead of the leaves separating from one another at the top of the bulb, a long stalk is formed between the bulb and the base of the leaves, Fig. 1. The pressure of this stalk is a sure sign of the existence of the disease, and it affords a ready means of recognising affected plants in a large patch of onions.

Atmospheric conditions favourable to the spread of the disease.

The conditions of the atmosphere which are favourable to the development and growth of the fungus, and hence to the progress of the disease, are heavy dews or rains followed by warm, moist, calm weather, and the absence of direct sunlight and strong winds. Shady and sheltered spots are usually the most liable to be attacked.

The land along the south side of Bermuda usually keeps free from the disease, and this freedom from attack is attributed by the planters to the fact that there the onion plants are exposed to the early morning sun and to the prevalent northerly winds, which rapidly cause the dew to evaporate.

The progress of the disease is sometimes arrested, after it has appeared in a field, by cold windy weather and strong sunshine, but this is rarely the case; as a rule, when it has once appeared it spreads with great rapidity, large fields becoming affected in the course of a single night.

Sect. II.—The Structure and Life-History of the Fungus Peronospora Schleideniana.

Structure of an onion leaf.

In order to fully understand the structure of the fungus *Peronospora Schleideniana* and the various stages of its growth, or its "life-history," it will be necessary to have some idea of the structure of the onion leaf upon which it flourishes.

When a thin slice of an onion leaf is examined through a microscope, it is seen that the tissue of the leaf is built up of a number of small cells, each with a definite wall. Inside this wall is the living matter of the plant, and in the cells near the surface the green substance termed chlorophyll, which gives the plant its characteristic colour. These cells are shown at cc., Fig. 3.

The cells are bounded on the outside by a special layer of cells, which form an outer skin for the leaf. These cells, shown at ep., Fig. 3., differ somewhat in appearance from those within. The layer which they compose is termed the *epidermis*.

On a somewhat closer observation of the slice of onion leaf, it will be noticed that the cells have not their sides in contact at all points, but that spaces occur here and there between the neighbouring cells. Such intercellular spaces are shown at ip., Fig. 3. In other words, the cells are not packed closely together as bricks in a wall, but considerable space exist between them, as between bricks when piled up roughly in a loose heap.

In these spaces between the loosely arranged cells the air circulates freely. No spaces occur between the cells forming the epidermis, but special mouths or *stomata* exist, through which the air can enter, and these circulate through the tissues of the leaf, STO., Fig. 3.

It is of the utmost importance for the health of the plant that these air-passages should be kept open, so that the air can have ready access to the cells of the leaf.

The number of stomata through which the air passes is very great, as many as 70,000 exist upon one square inch of onion leaf.

Structure and life-history of Peronospora and Schleideniana.

Having now considered the structure of the leaf of the onion, we can return to the fungus which lives upon it, and then the importance of this preliminary description will become evident.

Fig. 2. represents the surface of a small piece of the leaf of a diseased onion plant examined under a microscope. The outlines of the cells forming the epidermis are shown at EP.; STO. represents one of the stomata, through which, in the healthy plant the air has access to the spaces between the cells composing the tissue of the leaf. At STO. it will be seen that the opening of the stoma is checked by a tube-like stem (ST.), which protrudes from the leaf.

At its outer end this tube splits into many branches, and at the end of some of the branches is a little oval body, which hangs from it like a drop of water. These little bodies are the *Spores*, and they act as seeds. It is by their means that the fungus is able to reproduce itself. Some of the spores have fallen off from the ends of the branches, and are lying on the leaf (SP.).

This branching stem with its spores is the mature fungus *Peronospora Schleideniana*, and is the collection of these which causes the powdery appearance on the diseased onion leaf.

There is a slight but distinct violet colour seen both in the fungus and its spores.

If a thin slice or section of the diseased onion leaf, which passes directly through one of the stomata, be examined, it will be possible to follow the stem of the fungus through the epidermis into the tissue of the leaf and see what comes of it.

Such a section is represented at Fig. 3; STO. is the stoma, through which emerge in this case two stems. These branch at their outer ends, and some of the branches still bear spores; others, however, have lost them. The lower end of each stem can be traced through the stoma into the leaf, and there it will be seen to split into two tubular root-like processes (TP.), which in their turn branch again, and thus, by continually dividing, a meshwork of tubular roots is formed which passes in every direction through the spaces between the cells.

The injury which the fungus does to the onion plant is chiefly due to this network of roots, and it is of two kinds. Firstly, by blocking up the stomata and the passages between the cells it prevents the circulation of air through the tissues, and thus, in a measure, chokes the plant. Secondly, the fungus lives upon the substance of the plant, absorbing, by means of its meshwork of tubular roots, the nutritive matter formed in the cells of the leaf.

The very intimate relation which exists between the fungus and the tissue of the leaf is most noteworthy. The tubular roots pass everywhere between the loosely arranged cells, forming a complete network in the meshes of which the cells of the leaf lie. The importance of this close connexion will be more evident later when remedial measures are discussed.

As this network of roots grows and spreads through the tissue, some of its tubular branches force their way into the neighbourhood of a stoma, and pass out through it into the air, Fig. 4. ST. The young stem thus formed now commences to fork or branch, as is indicated in Fig. 5, ST. The branches again divide, and ultimately small portions of their tips are constricted off and form the spores before mentioned, It has been stated that the number of stomata upon the Onion leaf is roughly about 70,000 to the square inch. If the onion is badly diseased one of the branching stems of the fungus will be found projecting into the air through about one stoma in every ten. In some cases two (Fig. 3) and even three (Fig. 4) stems may emerge from one stoma, so that on a square inch of a diseased onion leaf we may fairly estimate the number of stems of the fungus as almost one-tenth of the number of stomata, that is 7,000. If we take 20 as the average number of spores upon one stem, and that is rather below than above the average, we find that a single square inch of a diseased onion leaf may have the enormous number of (20 × 7,000) 140,000 spores, each capable of reproducing the fungus, and hence the disease.

Reproduction, *a*. Asexual.

There are two methods by which the onion fungus reproduces itself: *a*, the asexual; *b*, the sexual. The asexual method of reproduction is effected by means of the above-mentioned spores. Each spore is an exceedingly minute sac or bag containing living matter; the shape is oval and rather more pointed at the end attached to the branch than at the other. It has a slight violet tinge.

These spores are, from their minute size and lightness, easily blown about by the wind, and float through the air, and it is by this means, and also by means of insects flying from one onion field to the next, that the spores are carried about and the disease spread over a field, and from one field to another.

Germination.

When one of the spores falls upon an onion leaf it will, providing certain external conditions are present, begin to germinate. These external conditions, which are necessary to the germination of the spore, are, firstly, a certain degree of warmth, and, secondly, a certain degree of moisture,—conditions which, unfortunately, are seldom wanting in Bermuda.

When a spore germinates upon the leaf of an onion it puts forth a long tubular outgrowth, Fig. 6, which makes its way to the nearest stoma and passes through it (Fig. 7). Once inside it begins to branch, forming a network of tubular roots inside the leaf; whilst at the other end the empty spore case drops off and the stem begins to divide up and form branches. Thus from the simple minute spore a fungus has arisen which closely resembles the parent form which bore the spore, and which will in a short time bear spores of its own capable in their turn of reproducing the fungus.

With respect to the germination of these spores and the consequent spread of the disease, two or three points are worthy of comment. Firstly, the spores will only germinate when a certain amount of moisture is present. Hence, when the sun is shining brightly or the wind is blowing and evaporation is promoted, the moisture disappears, the spores do not germinate, and for a time the progress of the disease is checked. On the other hand, during calm, warm, humid weather, the disease spreads with a rapidity which is only intelligible when the enormous number of spores is taken into account. Sharp showers of rain followed by sunshine will also tend to arrest the spread of the

disease, because many of the spores will be washed off by the rain on to the earth where they cannot germinate.

Secondly, the power of germination of the spores is not retained indefinitely. After a certain time the spores die if they have not found the conditions favourable to their development. The length of time during which they retain their vitality varies according to the circumstances ; if dried up, they would die in a day or two, but if the weather were moist they would probably retain their germinating powers some weeks. But as far as is at present known they do not retain their vitality beyond the summer in which they are matured. They would not last over from one season to another.

Thirdly, in connexion with remedial measures, it should be noticed that the spores when ripe and whilst germinating are outside the leaf, and have not entered into that intimate connexion with the tissues of leaf of the onion plant which is characteristic of the mature fungus.

b. Sexual.

It has been stated above that the spores of the fungus do not retain their vitality from one season to another, and it is obvious that the length of life of the mature fungus is limited by that of the onion upon which it lives. Hence there must be some means by which the fungus is enabled to last over the autumn and winter until the young onions of the new crop are ready to afford it a new home. This is effected by means of special cells, termed *Resting-spores*, which are formed in the following way.

Certain of the tubular root-like processes which form the meshwork inside the tissue of the leaf swell up at their ends. Thus a knob is formed full of living matter, and this is cut off from the contents of the rest of the fungus by the formation of a transverse partition. In the same neighbourhood as this knob a similar but smaller one is formed in much the same way. When these are both ripe a small canal is formed which connects the two knobs, and the contents of the smaller one passes through into the larger, and there fuses with the contents of the latter (Fig. 8). After this is accomplished the larger knob surrounds itself with a very thick wall or coat, and is now termed a resting-spore (Fig. 9).

A very large number of these resting-spores are formed, so that in a section of an onion leaf, which has been diseased for some time, a great number of these, each surrounded by a thick coat, are formed.

The function of these resting-spores is a very important one: it is by their means that the fungus is kept alive from one season to another. Their vitality is very great ; not only do they retain their power of germinating for a great length of time, probably for two or three years, but they are capable of withstanding considerable variations in the degree of temperature and moisture. This is largely owing to the thick wall which encases them.

When a field of onions has been destroyed by the Onion fungus, the withered leaves are crammed with resting-spores. The leaves fall to the ground, carrying with them thousands of these little bodies, any one of which is capable of reproducing the fungus, and hence the disease. They remain in the dried up leaves, or if the leaves are dug in, in the ground, until a new crop of onions grows up, the leaves of which afford them a suitable home. Then with the first moist warm day they begin to germinate, and soon the new crop of onions falls a victim to the fungus, produced from resting-spores which were themselves produced from the fungus of the preceding crop.

Sect. III.—The Origin of the Disease.

It is impossible to say by what means the fungus *Peronospora Schleideniana* first reached Bermuda. There is but little doubt that the disease is identical with that which occurs occasionally in the Canary Islands, and which is known there as La Ceniza or La Escarcha, so that it is possible that it may have been imported thence with the onion seed, or more likely on the leaves of some onion plant. On the other hand, microscopic examination of many specimens of onion seed, brought over from the islands of Teneriffe and Palma, failed to reveal any traces of the spores of the fungus; and onions were raised from this seed, both in the Botanical Gardens of Kew and Cambridge, which were perfectly free from the disease. It is also to be observed that the wide distribution which the fungus is known to have—being found in many European countries as well as in some parts of the United States—would render it difficult to obtain seed suitable for the Bermuda market which would be entirely above suspicion.

The thick black coat which covers the seed is too dense and hard to be penetrated by the fungus, so that the seed cannot be directly injured by the fungus nor its germinating power affected. Although, in my opinion, the danger of infection by the seed is but very slight, I have in the section upon remedial measures suggested a method by which any spores existing in the seed might be destroyed without injuring the seed itself.

Connexion between artificial manures and fungoid diseases.

There seems to be some connexion between the extensive use of artificial manures and the origin and spread of fungoid diseases. The potato is frequently attacked and large crops destroyed by fungus which is nearly related to that causing the onion disease. The potato was introduced into England 300 years ago, and for about 250 years it flourished without, as far as is known, any disease appearing among the cultivated varieties. But about 50 years ago, the Potato Fungus, *Peronospora infestans* (Phytophthora infestans, De Bary) made its appearance, and has never since disappeared. Its appearance was roughly coincident with the first general use of artificial manures. A similar connexion might be shown to exist between the origin and spread of the onion disease fungus, which did not make its appearance till eight or 10 years ago, and the recent extensive use of artificial manures in the Bermudas.

Sect. IV.—Remedial Measures.

The question of remedial measures may be considered under three heads:—

i. What means may be taken to strengthen the onion plant, so that it may be better able to withstand the attack of the fungus when it makes its appearance?

ii. What means may be adopted to prevent the appearance of the disease another year, or how can the disease be stamped out?

iii. What curative methods can be employed when the fungus has appeared, and what means should be taken to prevent its spreading?

Strengthening the plant strain.

i. At present no one strain of onions is known to withstand the attack of the fungus better than another. Any experiments carried on with a view of testing the relative power of resisting the disease among the

numerous varieties of onions would necessarily require observations extending over some years. As far as is known at present the *red* varieties of onions suffer rather less than the white, but our knowledge on this subject is too meagre to justify any recommendations as to changing the seed.

The diseased onions do not produce flower heads ; there is, therefore, no fear that the seed is being weakened by being gathered from diseased plants.

Situation.

It will be obvious from what has been said above with regard to the germination of the spores, that whenever it is possible onions should be sown where they will obtain the morning sun and a fresh breeze. They should never be placed at the bottom of a hollow, nor in any position which is too sheltered either from the sun or wind. That the sun and wind have a great influence in arresting the disease is shown by the fact that the disease is practically unknown on the southern side of the Islands.

Transplanting.

The practice of transplanting the young onion undoubtedly weakens the plant for some little time, until its roots have taken hold of the new ground. Hence the plant at this period is peculiarly susceptible to the disease. In most parts of the United States and in some countries of Europe the seeds are sown generally by means of a drill, at such a distance apart as is deemed necessary for the bulb to fill, and the onion is never transplanted. By this means a period of weakness is avoided, during which the plant would be ill-prepared to resist the disease should it appear.

Manure.

It is important to emphasise the fact that manures must not be looked upon as a means of curing the disease, but simply as a means of strengthening the crop of onions.

With regard to the kind of manure it is the universal opinion amongst the onion-cultivators of Europe and America that natural manures are preferable to artificial. Of these that from the hog-pen is perhaps the best, and an excellent manure for onions is made by putting seaweed under the hogs. Stable manure is also very valuable, but it cannot be too strongly stated that the liquid parts of the natural manures are the most valuable, hence care must be taken to prevent their draining away. The manure should be well rotted ; during the fermentation which then goes on it loses little of its valuable constituents whilst it becomes more concentrated. At the same time some of its constituents are rendered more soluble, and hence are more easily washed into the soil and more readily taken up by the plant. If kept in heaps it should be turned once or twice, as by this means many of the seeds of weeds are destroyed.

Owing to the impossibility of keeping much stock in Bermuda the demand for farmyard manures greatly exceeds the supply. In this connexion it is worth drawing the attention of farmers to the compressed manure which is now being prepared by the Horse Car Companies of New York and Philadelphia, and sold by them at a moderate price.

Another manure which has been highly recommended for onions is wood ashes, either scattered on the surface at the time of sowing or mixed with swamp-muck in the proportion of one load of ashes to 10 or 12 of muck. This is said to answer well, but the large per-centage of potash in the ashes might, in my opinion, be dangerous where the onion disease is prevalent, as it has recently been suggested that potash manures foster the development and growth of fungoid diseases.

Guano is a very good manure when used in conjunction with others, but it should not be relied upon to the exclusion of natural manures. Owing to its very variable composition it should always be purchased on analysis, and samples should be analysed from time to time to see that what is supplied is up to the standard.

Weeds.

It is needless to insist upon the necessity of keeping the ground clean and free from all weeds, which should, when gathered together, be burnt.

Measures for stamping out the disease.

ii. When the onion disease has attacked the crops our attention is directed to two problems: Firstly, how to cure the crop; and, secondly, how to prevent the disease spreading. I have postponed considering what means may be adopted with a view of curing the diseased plants until the third part of this section, and at present I propose to consider what means may be adopted with a view of preventing the spread of the disease both as regards space and time. How can the disease be prevented from passing from one field to the neighbouring fields, or from one season to the next?

The means by which the fungus spreads from one centre in a field all over it and thence into neighbouring plantations are, as we have seen above, the small spores which are abstricted from the ends of the branches of the fungus.

Owing to their very minute size and their lightness they float easily in the air, and are borne in countless numbers towards whichever direction the wind sets. Other agents by which they are dispersed are insects, birds, and even snails and slugs; in short, the spores may fall upon anything and be carried into another plantation.

The spores exist in such countless millions that when the weather is favourable, that is, warm and moist, the disease spreads with such rapidity that it is impossible to cope with it. But, on the other hand, if after the first appearance of the fungus the weather should change and become cold and dry, the disease will probably be confined to a small area of the affected field, and in this case efforts may be made to arrest the progress of the disease with some chance of success.

All affected plants must be carefully collected and *burnt*. Since the presence of the fungus on an onion arrests the growth of the plant but little is lost by collecting the diseased parts, that is, the leaves. The bulb, if it is already formed, may still be used.

Great care should be exercised in collecting the diseased plants, so as to avoid as much as possible knocking off the spores, and the plants should be carried off the field in some closed receptacle, such as a tin box. If carried off loosely or in a basket there is much danger of the collector spreading the disease.

The parts collected should be carefully burned. As we have seen, the fungus bears millions of spores capable of reproducing the disease at once; and it also at a later stage produces immense numbers of resting-spores, which are capable of living in the earth until the next season, and then germinating on the new crop and so carrying on the disease from one season to another. So that by burning the affected onions we destroy both kinds of spores and greatly diminish the chance of its spreading.

When it is impossible to burn the refuse it should be mixed with quicklime and buried at a considerable depth, but whenever it is possible, burning is safer.

The same recommendations also apply when the disease is at its worst. If a field of onions has been completely destroyed by the disease, the

refuse of the plants must be burned. *On no account must the refuse be dug into the ground;* this is simply sowing the seed for a new crop of fungus, which will be waiting for the next lot of onions planted on the land.

If, whenever the disease makes its appearance, the affected parts of the onion are burned, there is some hope that in course of time the disease may be stamped out of the Islands. But this is only likely to be the case if the destruction of the refuse is universally practised. It is little use for one farmer to burn the diseased plants if his neighbour does not. And it must always be borne in mind that a small patch of diseased onions, only a few square yards in area, will produce enough spores to infect every onion plantation in the Islands.

It has been shown that the onion disease is perpetuated from one season to another by means of resting spores which lie in the ground during the summer and autumn, and which germinate when the new crop of onions begins to appear. In northern climates it is probable that many of the resting-spores are killed by the frost; unfortunately we cannot reckon upon the assistance of this agent in Bermuda.

Rotation of crops.

But the fact that resting spores are in the ground suggests the advisability of rotating the crops. Although most crops when highly cultivated suffer from one or more fungoid diseases, the diseases are not as a rule interchangeable. For instance, the fungus of the potato disease does not attack onions, and the onion fungus cannot live upon tomatoes. Hence, if potatoes or tomatoes be planted in a field, the earth of which is full of the resting spores of the onion fungus, the latter will not germinate and ultimately die.

There have been no direct experiments to determine how long the resting-spores of the onion fungus retain their power of germination, but probably not for more than two or three years. Hence, if a piece of land has been severely visited by the disease, it would be advisable to plant it with a different crop for a year or two. This would afford some chance of the resting-spores dying out.

The rotation of crops, principally with potatoes, is universally practised by the onion farmers of the Canary Islands, and is the common practice in Europe, not so much because of the disease, but as a means of preventing the exhaustion of the soil. Hence, apart from the chance of diminishing the amount of the disease, it would be advantageous to adopt this method of culture.

Deep trenching.

In cases where it is impossible to rotate the crops, and where onions must be planted in ground which was infected last year, deep trenching may be recommended. By this means the resting-spores would be buried at such a depth that they would fail to reach the surface and come in contact with the new onion crop.

Early sowing.

Planting early in the autumn has been found to answer well in England as a means of avoiding the disease. When this is done the onions are fully grown before the weather is warm and moist enough for the fungus to make its appearance. Owing to the difference in climate between England and Bermuda, it is hardly safe to predict that the same result would follow in the latter place, but the experiment might be tried.

If there is any reason to suspect that the farmyard manure is a means of infection, through some refuse of a diseased onion crop being mixed with it, or from any other cause, it would be advisable to water the manure with a weak solution of iron sulphate (F_2SO_4) before putting it on the land. One-tenth of a gramme in 100 grammes of

water, or a solution of one-tenth per cent. is sufficiently strong to kill the spores of the fungus. Again, if the seed is considered to convey the infection, they may be soaked in a solution of the same strength. This will effectually kill all the spores of the fungus, and leave the seed entirely uninjured.

Curative manures.

iii. In looking for some curative means by which it may be possible to rid the onion crop of the disease, the value of the knowledge of the life-history of the fungus causing the disease becomes apparent. For the question now arises, at what stage in the life-history of the fungus should we apply such chemical remedies as we may have at our disposal.

We have seen that the fungus in its mature condition is structurally in intimate connexion with the tissue of the onion leaf. The root-like processes of the fungus form a network which everywhere penetrates the tissue, and the greater part of the fungus spends the whole of its life inside the leaf. It is obviously not advisable to attempt to kill the fungus at this stage, since any chemicals which would act upon the fungus would be almost sure to injure the leaf of the onion plant.

On the other hand, when the spores are germinating on the leaf they are outside the tissue, and have not entered into any close relation with the plant. Furthermore, the first outgrowths from the spores are very delicate and more easily acted upon by chemicals than the older parts of the fungus, so that when a patch of onions shows signs of the presence of the disease the remedies should be at once applied, not so much with the hope of destroying the mature fungus already there, but with a view of destroying the spores which it bears while they are germinating, and thus arresting the progress of the disease both in the affected plants and also from them to others.

Quicklime and sulphur.

The first of the chemical remedies which may be applied to the diseased plants with considerable prospect of success is a mixture of freshly burnt quicklime and sulphur.

There can be no difficulty in obtaining plenty of quicklime in Bermuda, and for this purpose it must always be used when freshly burnt as quicklime loses its caustic properties and undergoes chemical change when kept any length of time. After burning it should be crushed to a powder and mixed with powdered sulphur in the proportion of two parts of quicklime to one part of sulphur.

This mixture may be sprinkled on the diseased plants by hand or more effectively by means of bellows, such as the Kentish hop-growers use for sulphuring the hops.

The mixture should be applied before the dew is off the plants or after rain whilst the plant is still wet.

The chemical interaction which is produced by the mixture of sulphur and freshly-burnt quicklime leads to the formation of sulphurous acid and other allied gases. The gases are evolved slowly, and being readily diffusible they soon spread over the plant, and being easily soluble in water they dissolve in any moisture in the leaves, &c. The solution thus formed is strong enough to kill the germinating spores without injuring the plant, and it does not become concentrated to a dangerous degree. The final products are not harmful to the plant or soil, and the chief use of sulphate of lime is a valuable manure, especially in Bermuda, where the amount of sulphur in the soil is very slight.

Iron sulphate.

A second chemical remedy which may be used for the onion disease is iron sulphate (F_2SO_4), and this has the advantage of being readily soluble in water, and hence can be applied in the liquid form. When in a weak solution the iron sulphate will kill the fungus

without killing the onion plant. The solution should contain one-tenth part $FeSO_4$ to 100 parts of water. It may even be made as strong as three-twentieths per cent. without injury to the plant, but anything stronger than this is like to prove injurious.

The diseased onions may be watered with this, or, still better, sprayed thoroughly. The ground in the vicinity of the affected plants may also be watered with advantage with this solution; in this way any spores which have fallen off will be destroyed.

In addition to its antiseptic properties iron sulphate forms a very valuable manure. In a paper published in the Journal of the Chemical Society, 1886, Mr. Griffiths has described many experiments which all tend to show the value of this chemical as a manure. I will content myself with quoting from his paper the results of one experiment. Mr. Griffiths sowed three plots of ground the same size with potatoes. The first plot of ground was not manured: from this he gathered three tons of potatoes. The second plot, which was well manured, gave six and a half tons; whilst from a third plot, which was well manured in the same way as the second, but with the addition of iron sulphate, he obtained eight and a half tons of potatoes. This is only one experiment out of many which all tend to show the value of iron sulphate as a manure.

The iron sulphate should be applied as a top-dressing after the plants have been transplanted. About half a hundredweight should be used to the acre: more than this is apt to prove harmful.

It has been found that wheat crops grown in fields manured with iron sulphate do not suffer with the wheat mildew, and it is very probable that if the land be treated in the manner indicated, potato and onion crops would also escape the fungus.*

Iron sulphate has the further advantage of being very easily obtainable at a very moderate cost.

Sect. V.—Macrosporium Parasiticum.

There is a second fungus found living upon the onion plant. This is known as *Macrosporium parasiticum*, and it is one of the Pleosporous Ascomycetes.

This fungus is only found upon the onion after it has been attacked by the *Peronospora*, when the leaves are already dead or dying. It does not attack the healthy plant.

Macrosporium belongs to that class of fungi which are known as Saprophytes; these are characterised by living upon dead or decaying organic matter. They are unable to effect a foothold upon the healthy plant. Hence if the *Peronospora* can be exterminated, the *Macrosporium* will disappear at the same time.

The fact that the *Macrosporium* is, so to speak, a sequel to the *Peronospora*, and that with the extermination of the former the latter will disappear, renders it unnecessary to describe the very complicated and incompletely known life history of the fungus. But a short account of its naked-eye appearance may be given.

After the plant has already been weakened by the *Peronospora*, the *Macrosporium* makes its appearance as patches of a deep black colour and velvety appearance. These gradually spread, forming belts an inch or more wide round the leaf. This dense black appearance is followed by a fluffy white growth, which stands out from the leaf for the distance

* All the remedies suggested for the onion disease apply with equal force to the potato disease, which is caused by a fungus, *Peronospora infestans*, a species distinct from *Peronospora Schleideniana*, but resembling it in its life-history.

of one-tenth inch. Whilst the *Macrosporium* is growing the leaf continues to rot; it does not dry up as it does when only attacked by the *Peronospora*, but the plant retains a good deal of moisture, and when thoroughly rotten gives rise to a most offensive smell. The bulb is also sometimes affected.

The dense black colour of this fungus is so much more conspicuous than the whitish powder of the *Peronospora* that it is sometimes stated to attack onion crops which have not suffered from the *Peronospora*. Closer observation, however, shows that it invariably follows the fungus.

It is the *Peronospora* which does the great harm to the onion crops, and the *Macrosporium* is only a sequel to it. Hence all remedial measures must be directed against the former, for with its extermination the *Macrosporium* will disappear.

Sect. VI.—Insects.

There is a very minute insect, a species of Thrips, which occurs occasionally, though not in any great numbers, at the top of the bulb in the angles between the leaves of the full-grown onion plant. It occurs in the onions usually in the larval condition, as a yellowish white grub with three pairs of legs, but no wings. During this stage it lives upon the substance of the onion leaf. The adult insect has a much darker, brown and black appearance, and is provided with two pairs of wings. In this stage it is very much less common in the leaf than in the larval condition.

This insect was found in comparatively few farms, and then in very limited numbers. It does not burrow through the leaf, and appears to cause very little damage to the onion plant. Should, however, the numbers increase largely, or should it appear upon the young seedlings, it might be the cause of serious loss.

A simple way of getting rid of it is to water or spray the affected plants with a solution of iron sulphate, such as was recommended in Sect. IV. iii. This would more particularly prove effective in the case of the onion, because some of the solution would collect in the angles of the leaves where the insect most commonly occurs.

The onion fly, *Anthomyia ceparum*, whose maggots do much harm by eating through the bulb of the onion, occurs so rarely in Bermuda, that it hardly calls for remark in this report. I only met with a single instance of it during my stay in the Colony.

In case, however, that it should at any future time prove troublesome, it is worth mentioning here that Miss Ormerod has successfully dealt with this insect by covering the bulbs with a thin layer of earth, so that they no longer stand out of the ground. This in no way injures the plant, and prevents the fly getting at the bulb to lay its eggs.

Sect. VII.—Summary.

1. The onion disease is caused by a fungus *Peronospora Schleideniana*, which lives parasitically upon the leaf of the onion plant.

2. The atmospheric conditions which favour the progress of the disease are heavy dews or rains followed by warm, moist, calm weather, and the absence of direct sunshine and cold winds. In favourable weather the progress of the disease is very rapid.

3. The fungus lives in the tissues of the leaf, choking up the air passages and absorbing the nutritive fluid formed in the cells. Its

stem protudes through the stomata of the leaf into the air. Its branches bear spores at their tips.

4. The reproduction of the fungus is effected by means of these spores which float about through the air, and also by means of certain special cells formed by the fungus and known as resting-spores. These pass the winter in the earth, and are capable of retaining the power of germination for two or three years. It is by their means that the disease is carried on from one season to another.

5. One method of combating the disease is to make the onion plants as strong as possible, so as to withstand the attacks of the parasite. Hence the site should be carefully selected, the soil well prepared, good manures used, and the land kept clean and free from weeds.

6. To prevent the spreading of the disease all affected plants must be collected and burned. Whilst doing this care must be taken that the collector does not himself spread the disease by carrying the refuse loosely. Rotation of crops, or, when this is impossible, deep trenching, would lessen the chance of the disease appearing.

7. Diseased plants may be treated with a mixture of powdered sulphur and freshly burnt quicklime sprinkled by hand or by bellows; or they may be washed or sprayed with a weak solution of iron sulphate (green vitriol). In both cases the fungus is destroyed without injury to the onion plant. Further, both these chemical remedies have the additional advantage of being excellent manures.

8. Another fungus, *Macrosporium parasiticum* sometimes attacks the onions after the *Peronospora* has taken a good hold of the plant and weakened it. As this only occurs as a sequel to the *Peronospora*, the extermination of the latter would involve the disappearance of the former. The *Macrosporium* does not attack the healthy plant.

9. Only two kinds of insects, the onion thrips and the onion fly were met with, and the latter on only one occasion. The thrips were not numerous and appeared to do little harm. They can easily be removed by application of a solution of iron sulphate, such as is recommended in Section IV. iii.

Should the onion fly ever prove a serious pest it may be dealt with by covering the bulb of the onion with a thin layer of earth. This prevents the fly approaching the bulb to lay its eggs.

(Signed) Arthur E. Shipley.

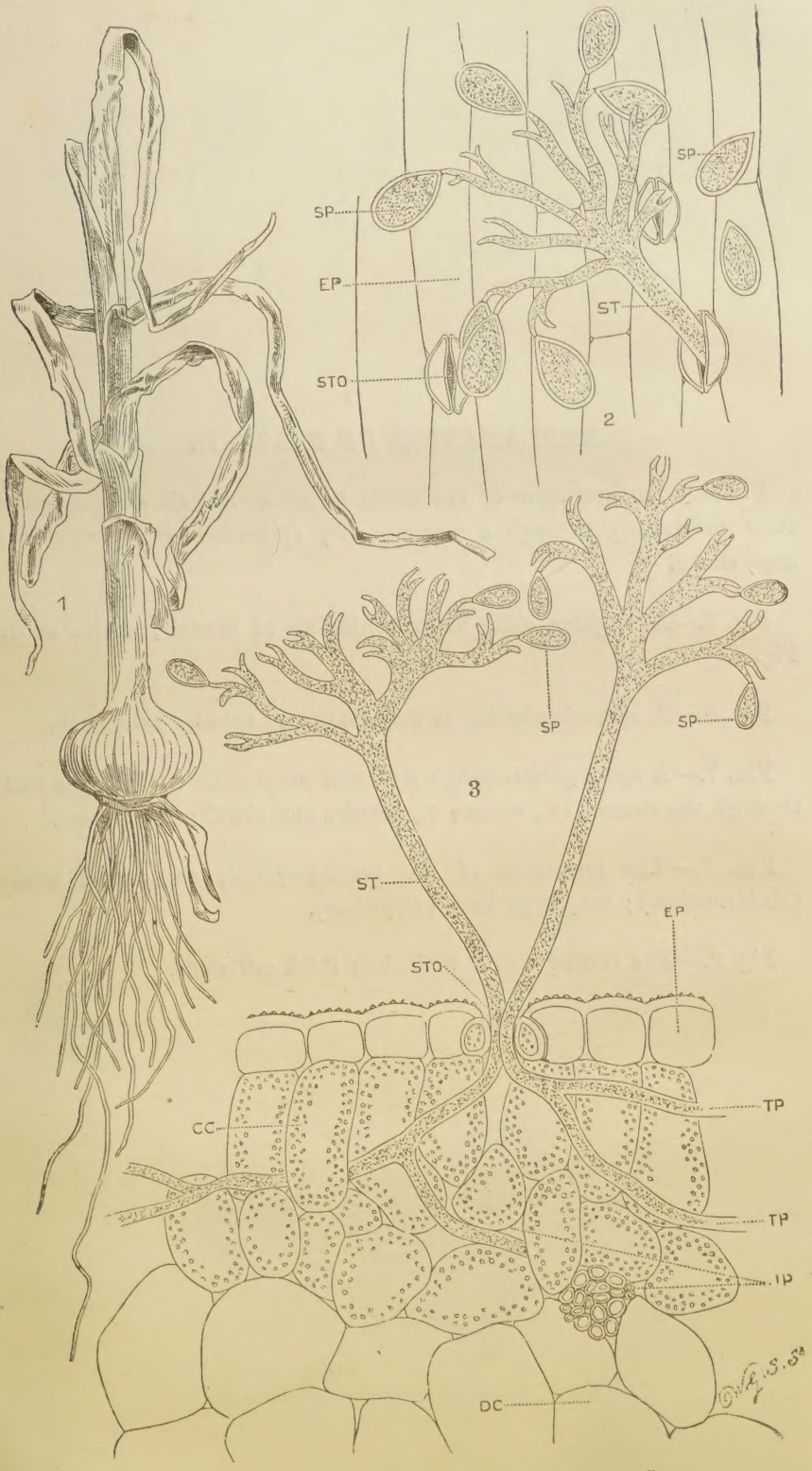
Christ's College,
Cambridge,
August 3, 1887.

EXPLANATION OF PLATE I.

Fig. 1.—An onion plant which has suffered severely from the disease, showing the withered bent-down leaves and the long stalk.

Fig. 2.—Surface view of the epidermis of an onion leaf with a fungus stem protruding through a stoma. Magnified about 200 diameters. EP., epidermal cells; SP., spores; ST., stem of fungus (*P. Schleideniana*); STO., stomata.

Fig. 3.—Section through an onion leaf, showing cells of the leaf and the air spaces between them in which the root-like processes of the fungus grow. The section passes through a stoma, and shows two stems of the fungus passing into the air and bearing spores (× 200); CC., chlorophyll cells, which give the leaf its green colour; DC., deeper cells not containing chlorophyll; EP., epidermal cells; IP., air passages between the cells; SP., spores; ST., stem of the fungus; STO., stomata; TP., tubular processes ramifying in the air passages.



Peronospora Schleideniana, De Bary. PLATE I.

EXPLANATION OF PLATE II.

Fig. 4.—Surface view of epidermis of onion leaf showing a young stem protruding through a stoma. EP., epidermal cells; ST., stem; STO., stoma.

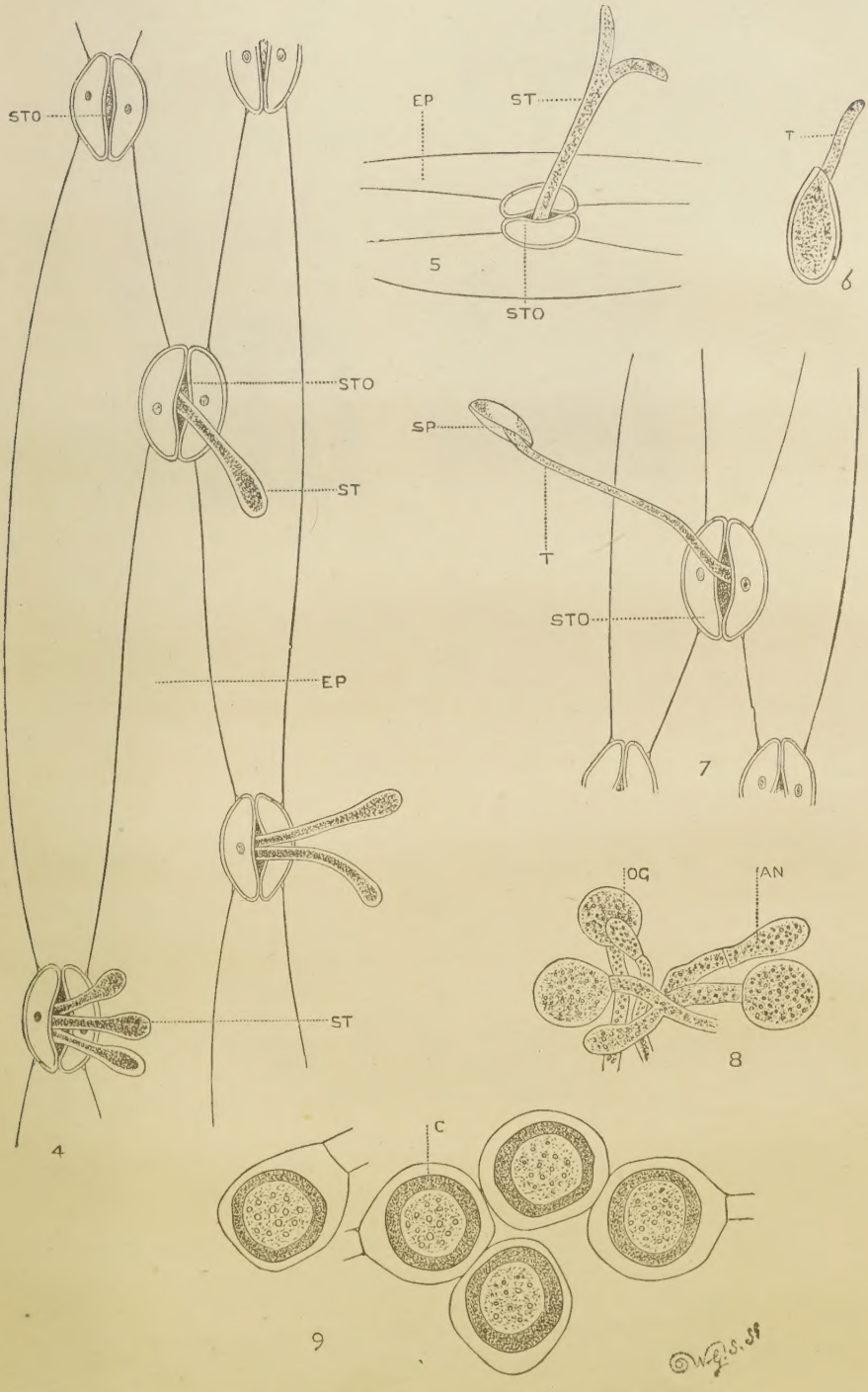
Fig. 5.—A slighter older stem beginning to branch; letters as in Fig. 4.

Fig. 6.—A spore beginning to germinate; T., tubular outgrowth.

Fig. 7.—A spore germinating; a tubular outgrowth entering the leaf through the stoma; SP., spore; T., tubular outgrowth; STO., stoma.

Fig. 8.—The formation of the resting-spores; AN., small knob (*Antheridium*); OG., large knob (*Oognium*).

Fig. 9.—The resting-spores with their thick cell-walls.



Peronospora Schleideniana, De Bary. PLATE II.